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DEGREENING RESPONSE OF COLOR-SORTED FLORIDA ORANGES

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DEGREENING RESPONSE OF COLOR-SORTED FLORIDA ORANGES

(A Preliminary Report)

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SUMMARY AND CONCLUSIONS

Degreening studies were conducted with Hamlin or Parson Brown oranges during three seasons. The degreening response was found to be related to the initial intensity of green color as measured by visual or electronic color measurements. Dark green fruit took as much as 24 hours longer to reach an acceptable color and more of it failed to pass the color standards during the degreening periods than lighter green fruit. These results indicate that the efficiency of packinghouse degreening could be improved by color sorting fruit before degreening. The amount of time saved in degreening sorted oranges would depend on the color range and the number of color divisions made.

Visual and electronic (difference meter) color measurements showed similar patterns of fruit response. The light transmittance difference meter provided a more accurate measure of chlorophyll level in the fruit than was possible by visual means; however, the difference meter readings were affected by fruit size in these tests.

Fruit size had no apparent effect on the degreening response of oranges. Comparisons of fruit grown on rough lemon, sour orange, and Cleopatra mandarin rootstocks indicate that rootstocks also have no effect on the degreening rate.

Changes in weight and size of the oranges during degreening were small but evident. Size shrinkage of less than one-twentieth of an inch and weight losses of up to 2.9 percent were recorded after 84 hours' degreening. Though small, these losses are important. By shortening the time for degreening, color sorting would help to reduce these losses.

INTRODUCTION

In some citrus varieties the desired yellow or orange rind color does not develop until some time after the internal quality has reached a satisfactory level. The preference of the fresh fruit market for well-colored fruit has resulted in the practice of degreening fruit to speed up the natural color change (5).[1] Except for improving the color of the fruit, degreening serves no useful purpose. Instead, degreening conditions favor a marked increase in decay (8). Considerable fruit shrinkage also may occur, depending on the conditions maintained in the degreening rooms.

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[1] Underscored numbers in parentheses refer to Literature Cited, p. 14.

Generally, all fruit received at a packinghouse is degreened, although in a few houses presorting for color is combined with the grading of incoming fruit. This presorting is limited to the removal of fruit that is not expected to reach a marketable color with degreening. Rind color is an important factor in grading fruit as "culls (4). Although regulations specify color standards (2, 3, 12), these are of little value here. Such terms as "50 percent color break," "well-colored" or "fairly well-colored" are both subjective and relative and are meant to apply to a lot as a whole. This difficulty in defining color is perhaps why color is a continuing problem with grapefruit packers (6).

Because of the importance of fruit color in citrus marketing and the success obtained in preliminary tests, the investigations on color sorting of fruit were extended. In addition to removing those fruits that would be too green to be marketable, it appeared likely that fruit color intensity could be related to the degreening time requirement. By degreening uniformly colored lots of fruit, it should be possible to shorten the average time required, increase the efficiency of degreening room operation, and possibly improve the uniformity of fruit quality. Many factors are known or thought to affect fruit color and, therefore, possibly could have an effect on color sorting. Two of these, fruit size and rootstock, were included in the present studies. Since weight loss occurs during degreening, observations on this factor were also included.

METHODS

Studies of color in relation to degreening were made during the fall of three growing seasons, 1963, 1964, and 1965. Test procedures varied from season to season, but standard degreening conditions of 85° F. and 85 to 90 percent humidity were used in all tests. Degreening was done in experimental degreening rooms using ethylene supplied by the bubble method (5). In all tests degreening was begun the same day as and generally within 6 hours of harvest. Color, as used in this report, refers to the normal pigment systems of citrus--the chlorophylls (green) and carotenoids (yellow to orange). Color caused by other factors such as russeting or scarring was excluded. For all tests, fruit was sorted visually according to the intensity of green. The individual fruits were then rated visually using color plaques. These plaques were based on plate No. 3 in Technical Bulletin 753 (7) and numbered 1 to 12. Color 7 (yellow) corresponding to G in the plate was set as the passing color in grading with this system. Fruit passing this standard was considered marketable, whether or not degreening was required. Because of the variability in color of some fruit, grading was based on the minimum rather than the average color in these tests. Therefore, a fruit rated 7 might have some areas of orange as well as yellow, but no green areas. The percentage packed in the various tests represents the proportion of fruit passing the color standard and does not take into consideration other possible defects.

In October and November 1963, three tests were conducted with Parson Brown oranges. The fruit was sorted into light, medium, and dark green color groups with 100 fruits per group. The fruits were numbered, and a color rating based on the plaques was recorded for each fruit. No sizing was done in these tests. The fruits were placed in the degreening room. At 12-hour intervals they were taken out and a color rating was recorded. After 84 hours, all the fruit was removed and given a color rating.

In the 1964 season, the study was extended to compare the visual color rating by the plaques with an instrumental color measurement. The instrument, a difference meter (1), was a development of earlier instrumentation which was found to be capable of following changes in chlorophyll in intact citrus fruits (10, 11). This instrument passes two alternating beams of light through the sample being examined. With properly selected wavelengths, the relative density of the sample to the light of the two beams (ΔOD) is related to the color of the object. For these tests the wavelengths used were for the measurement of chlorophyll--695 nanometers (nm.) for the measuring wavelength and 740 nm. for the reference wavelength (9). The resulting measurement is directly related to the intensity of green, or the amount of chlorophyll in the path of the light beam. For this work, the instrument was equipped with a direct path illuminating system, which restricts light entering and leaving the sample to an area of about 1 1/8-inch diameter. For all measurements the light beam was passed through the center of the fruit parallel to its axis from stem to stylar end. For purposes of comparison to the plaque ratings, a reading of .080ΔOD on the difference meter was arbitrarily set as the passing color.

Two tests were conducted during November 1964 using Hamlin oranges grown on rough lemon rootstock. Because of the advanced fruit color, it was necessary to selectively harvest fruit in order to have an adequate color range of regular-bloom fruit for the tests. The fruit was washed and sized into three groups: large, medium, and small, which corresponded to commercial sizes of 163, 200 and 252. Each size group was visually sorted into three color categories: dark, medium, and light. Each color-size lot consisted of 10 fruits, and five replications were included.

Initially, each fruit was numbered and weighed; the height and diameter were calipered; and a color rating was given with both the instrument and plaque systems. Each lot of 10 fruits was placed in a mesh bag for degreening. At 12-hour intervals, the samples were removed and given a color rating with the difference meter and color plaques. The final reading after 84 hours' degreening also included fruit weight, height, and diameter measurements.

In 1965, a series of tests was run to study the effect of rootstock on the degreening of Hamlin oranges. Three rootstocks--rough lemon, sour orange, and Cleopatra mandarin--were used. The fruit samples were from trees of comparable age, growing in adjacent blocks.

Five tests were conducted between October 4 and December 13, utilizing 40 fruits from each rootstock for each test. After being washed, the fruit was degreened for 4 days and daily chlorophyll measurements were taken with the difference meter. During the last four tests, plaque ratings were also obtained daily. For these tests, ratings were not made higher than 7 which indicates that visually all chlorophyll had been lost. Fruit was not sized, but an effort was made to get a similar range in size in all samples. However, fruits on rough lemon rootstock tended to average larger than fruits from the other rootstocks.

In addition to measuring the shrinkage during the 1964 degreening tests, changes in fruit were followed in another series of tests during the 1962-63, 1963-64, and 1964-65 seasons. For these tests, samples of 20 fruits each were washed and numbered for individual fruit measurements. Data on weight and height were recorded as fruit was received and after the 40-hour treatment period. Treatments included 33° and 60° F. storage and degreening. During the 1962 season, single tests were made with Hamlin and Pineapple oranges. In 1963-64, four tests on Hamlin oranges and three on Valencia oranges were run. In 1964-65, two tests each were run on Hamlin and Valencia oranges. As indicated above, the humidity in the degreening room was maintained at 85 percent or higher. In the storage rooms the humidity was 90 percent or higher. The fruit was exposed to moderate air circulation in all treatments.

RESULTS AND DISCUSSION

COLOR SORTING TESTS

Results of the 1963 tests (table 1) show that the initial fruit color does affect degreening time. Most light green fruit was degreened in less than 48 hours, greener fruit required longer periods, and many failed to pass the color standard after 84 hours. Normally, a shorter average degreening time would be expected as the season progressed because of the natural color change. However, the fruits in these tests were color sorted so that a dark green fruit on October 20 was similar to a dark green fruit picked on November 3. The

TABLE 1.--Cumulative percentage of Parson Brown oranges packed in relation to fruit color at harvest and degreening time, 1963

Test date and shade of green	Hours degreened							
	0	12	24	36	48	60	72	84
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
October 20:								
Dark	0	0	0	1	6	20	48	57
Medium	0	0	0	3	36	65	74	88
Light	30	31	50	93	100	100	100	100
October 27:								
Dark	0	0	0	0	45	61	70	79
Medium	0	0	0	1	27	29	54	70
Light	46	64	100	100	100	100	100	100
November 3:								
Dark	0	0	0	3	38	55	64	69
Medium	0	2	4	11	41	76	84	90
Light	14	18	29	67	93	100	100	100

similarity between results for the three tests indicates that the degreening response is largely dependent on fruit color with little direct effect of maturity.

Based on plaque readings, most light green Hamlin oranges degreened to passing color in 1964 in 48 hours in test 1 (table 2) and in 24 to 36 hours in test 2 (table 3). Medium and dark green fruit took approximately 12 and 24 hours longer for 90 percent of them to be ready for packing. With the difference meter, a similar relation between initial color and time to degreen was found in both tests, but the differences were less than with the plaque ratings.

These results confirm that the time required to degreen oranges is dependent on the initial color of the fruit. It is impossible to degreen unsorted oranges for the proper length of time for all fruit. Color sorting would shorten the time in degreening for the most mature fruit, and greener fruit could also be degreened for the proper length of time. As in preliminary tests, when the plaque rating system was used, fruit size did not appear to affect the response of the fruit to degreening. With the difference meter, however, the larger fruits in any color class passed first, and many small fruits, even in the ligher green class, failed to pass after 84 hours. The problem of fruit size may be removed by change in instrument design. It also appears that the arbitrary passing standard of .080 ∆OD was too low for the small fruit since they did pass the plaque standard.

The changes in plaque ratings during the 1964 tests are shown in figures 1 and 2. These data show similar rates of color change with time (figs. 1A and 2A), except that the light-colored fruit approach a maximum color in test 2 (fig. 2A). In test 1 there was a discrepancy in readings at the 12- and 24-hour intervals. All ratings except these were made by the same person. The interaction in test 1, therefore, indicates that the person making these ratings did not rate them the same as the regular observer, illustrating the problem of duplicating visual color observations.

Little difference in the color ratings of the three fruit sizes was found in relation to hours of degreening in test 1 (fig. 1B), but the small fruit were greener in test 2 (fig. 2B). An interaction between fruit color and size was evident in both tests (fig. 1C and 2C). However, in test 1 the large fruit were rated greenest, whereas in test 2 the small fruit were greener, supporting the view that these were chance relationships because of sampling variability.

Changes in difference meter ratings for the two tests are shown in figures 3 and 4. Unlike the plaque ratings, these results show an increasing similarity of ratings for the three color groups with time as the chlorophyll level declined (figs. 3A and 4A). The difference meter recorded only chlorophyll levels, TABLE 2.--Cumulative percentage of Hamlin oranges packed in relation to time in degreening, measuring system, fruit color at harvest, and fruit size

Test 1, November 9, 1964

Measuring system, fruit color, and fruit size	Hours degreened							
	0	12	24	36	48	60	72	84
PLAQUE	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Dark green:								
Large	0	0	0	4	10	82	94	96
Medium	0	0	0	0	8	84	90	92
Small	0	0	0	4	6	78	88	88
Medium green:								
Large	0	0	0	10	48	84	98	98
Medium	0	0	2	30	72	100	100	100
Small	0	0	0	30	80	96	96	100
Light green:								
Large	0	0	0	62	90	100	100	100
Medium	12	16	20	70	96	100	100	100
Small	22	22	28	86	100	100	100	100
DIFFERENCE METER								
Dark green:								
Large	0	0	4	26	58	94	98	98
Medium	0	0	0	8	40	72	86	92
Small	0	0	0	0	4	20	30	40
Medium green:								
Large	0	6	38	72	92	96	100	100
Medium	0	2	12	42	64	78	88	96
Small	0	0	2	12	20	32	34	40
Light green:								
Large	4	32	64	88	96	98	98	98
Medium	0	16	24	44	64	84	90	92
Small	0	0	0	4	10	20	30	40

whereas the plaque ratings included changes in the yellow-orange pigments. Had the plaque system also been limited to chlorophyll measurement, maximum ratings of 7 would have been obtained and the resulting graphs would have resembled more closely those for the difference meter.

Fruit size affected the instrumental color measurements in both tests (figs. 3B and 4B), with the small fruit reading higher (greener). In test 1 the large fruit also changed color more rapidly than the smaller sizes. Effects of fruit size were also shown in the relationship between fruit size and color (fig. 3C and 4C). In all color groups, the chlorophyll levels were rated lower in the larger fruit than in the smaller.

As shown in table 4, many of the interactions shown in figures 1 to 4 were significant, including some involving effects of fruit size. Although undesirable, this effect of size on color measurements was not great, considering the wide range in size of fruit used. Correlations between fruit weight and initial difference meter ratings were -.425 for test 2 and only -.163 for test 1. Correlations at this level do not indicate that fruit size had a dominant effect on the chlorophyll ratings.

TABLE 3.--Cumulative percentage of Hamlin oranges packed in relation to time in degreening, measuring system, fruit color at harvest, and fruit size

Test 2, November 16, 1964

Measuring system, fruit color, and fruit size	Hours degreened							
	0	12	24	36	48	60	72	84
PLAQUE								
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Dark green:								
Large	0	0	0	28	50	84	90	96
Medium	0	0	0	6	34	84	88	92
Small	0	0	0	4	34	86	96	98
Medium green:								
Large	0	0	34	82	96	100	100	100
Medium	0	0	36	84	96	100	100	100
Small	0	2	6	26	56	94	94	94
Light green:								
Large	20	58	94	100	100	100	100	100
Medium	38	72	96	100	100	100	100	100
Small	14	44	78	92	100	100	100	100
DIFFERENCE METER								
Dark green:								
Large	0	4	44	83	94	96	100	100
Medium	0	0	6	60	84	96	98	100
Small	0	0	0	14	30	30	56	56
Medium green:								
Large	12	50	80	98	100	100	100	100
Medium	0	18	38	88	98	100	100	100
Small	0	0	2	26	42	56	68	72
Light green:								
Large	56	82	94	98	100	100	100	100
Medium	36	56	68	86	92	94	94	96
Small	0	2	28	44	58	68	78	80

Although many of the interactions were significant, it should also be noted in table 4 that the major factors affecting the ratings were hours of degreening and the color groups. The significant difference between color groups is particularly important since this would be the basis for color sorting.

Comparison of the difference meter results with those for the plaques shows that the instrument is capable of a much wider separation than is possible visually. The small number of potential classes with the plaques probably explains why the correlations between these two measurements, -.643 and -.713 in the two tests, were not higher for the initial fruit color ratings. This limited visual separation also may have been a factor in reducing the correlations between the initial color ratings and the time in degreening needed to reach the visual passing color. These correlations were -.773 and -.801 for the plaques and .592 and .704 for the difference meter. The greater spread in ratings with the difference meter should permit a better and more flexible color sort than could be done visually.

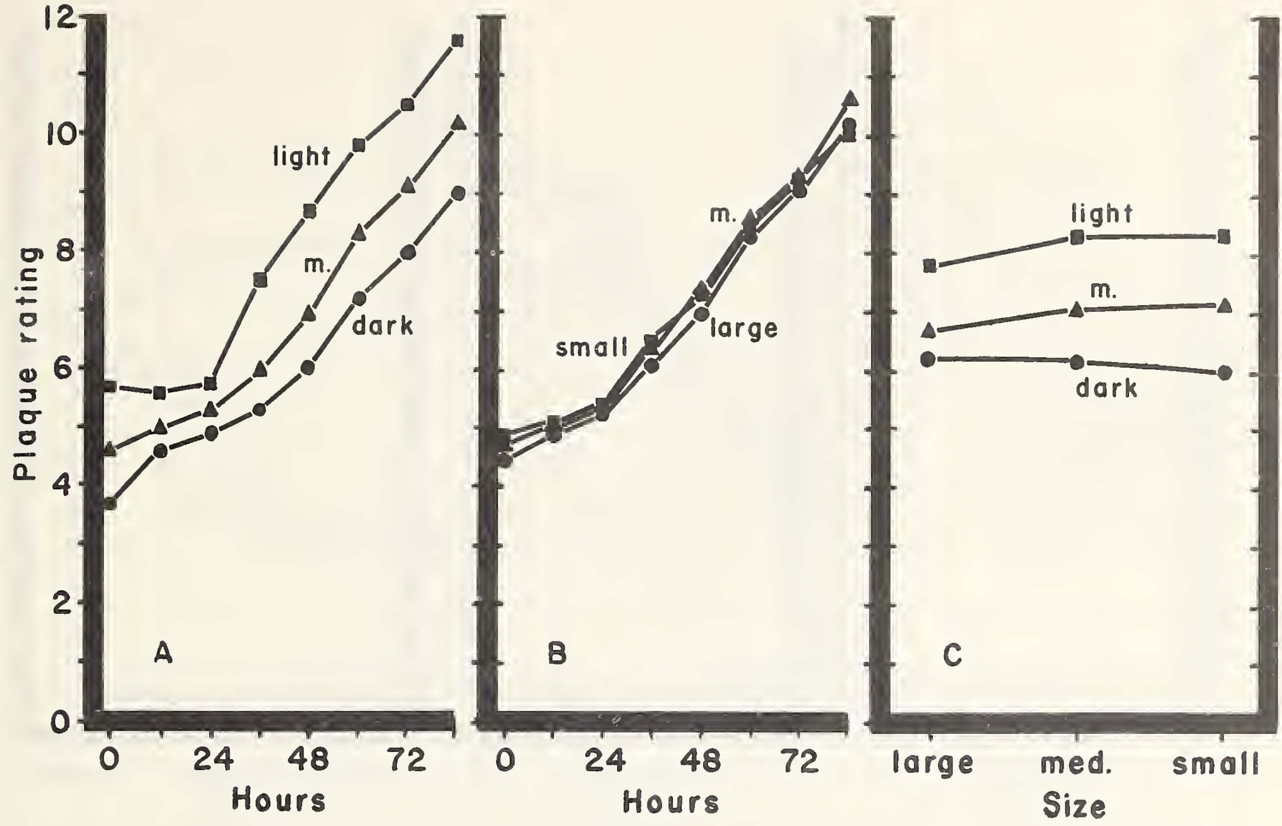

Figure 1.--Color relationships in plaque ratings, Test 1, 1964. Color ratings in relation to (A) color groups and hours of degreening; (B) fruit size and hours of degreening; (C) color groups and fruit size.

ROOTSTOCK TESTS

The rootstock was found to have some effect on the chlorophyll level in the fruit in these tests as shown in figure 5. Hamlin oranges from Cleopatra mandarin rootstock were consistently greener than fruit from sour orange or rough lemon rootstock, according to both the difference meter and color plaques. With both measurements restricted to chlorophyll in these tests, the similarity in changes during degreening are apparent. The difference between fruit from rough lemon and the other two rootstocks may have been exaggerated by the difference meter in these tests because of the larger size of fruit from rough lemon rootstock.

Although these tests showed significant differences in the color of Hamlin oranges from different rootstocks, no effect on the degreening response was apparent. Fruit of a given color generally required the same length of time in degreening, regardless of the rootstock used. These results are based on only one series of tests, but they indicate that effects of rootstocks on fruit color probably would not be important in the use of color sorting for degreening.

PRESORTING FOR DEGREENING

The results of these tests confirm that degreening time is related to the initial fruit color. It should, therefore, be possible to sort incoming fruit based on their need for degreening and increase the efficiency of the operation. In practice, the fruit would be sorted into two to four classes, depending on the range of color present. If the fruit were clean or washed, it could also be graded before degreening. If practical, this would eliminate culls from the degreening rooms as well as fruit too green to be properly colored.

This system would increase the overall efficiency of degreening room operation since only salable fruit would be handled, and the degreening time would be shortened. The harmful effects of degreening would then be reduced on the fruit of more advanced color, some of which may not need any degreening.

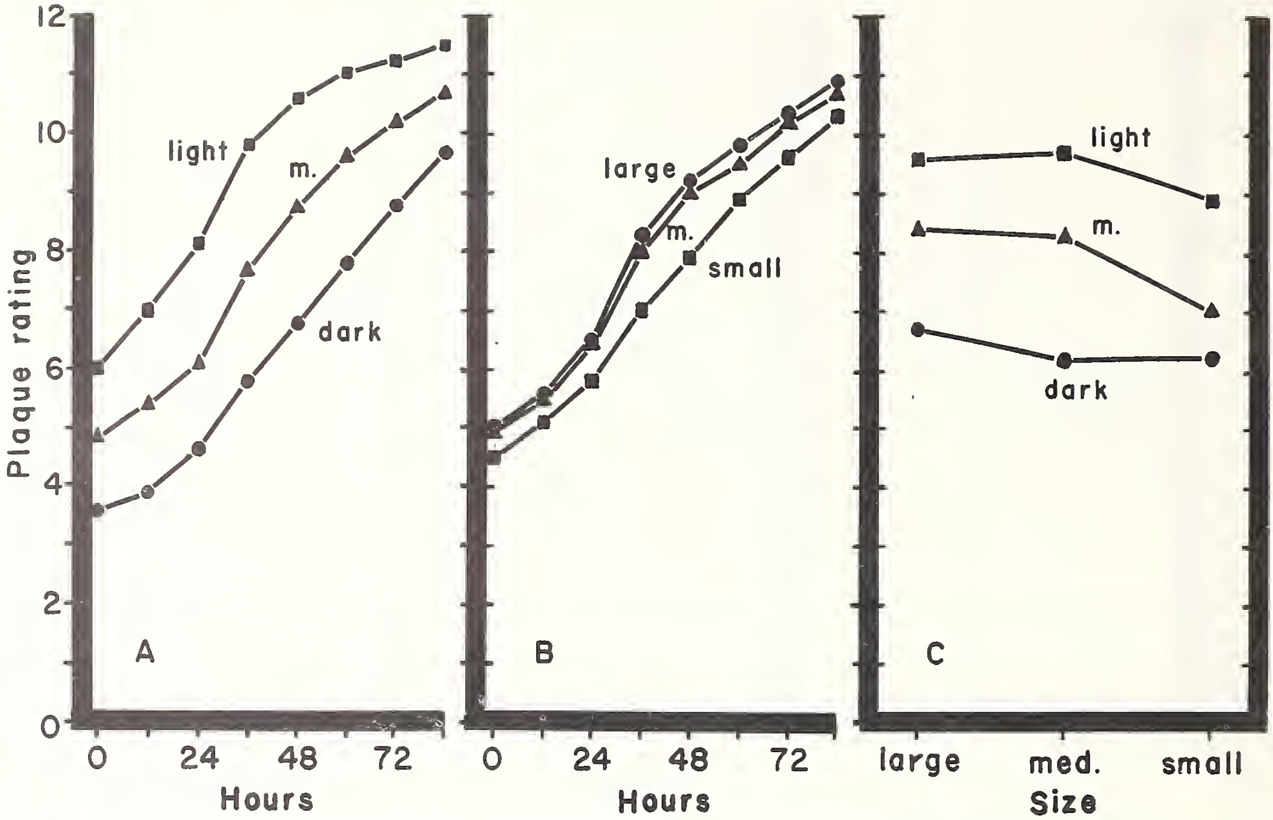

Figure 2.--Color relationships in plaque ratings, Test 2, 1964. Color ratings in relation to (A) color groups and hours of degreening; (B) fruit size and hours of degreening; (C) color groups and fruit size.

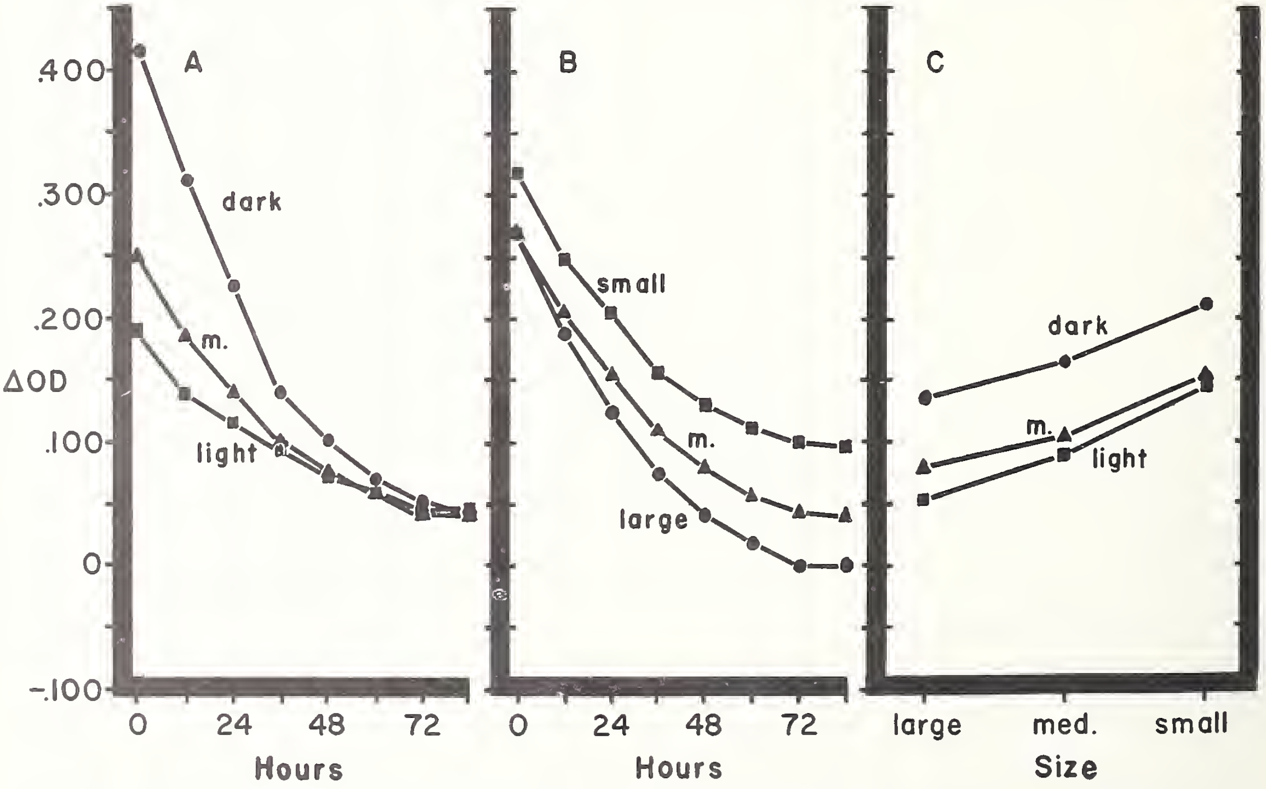

Figure 3.--Color relationships in difference meter ratings, Test 1, 1964. Color ratings in relation to (A) color groups and hours of degreening; (B) fruit size and hours of degreening; (C) color groups and fruit size.

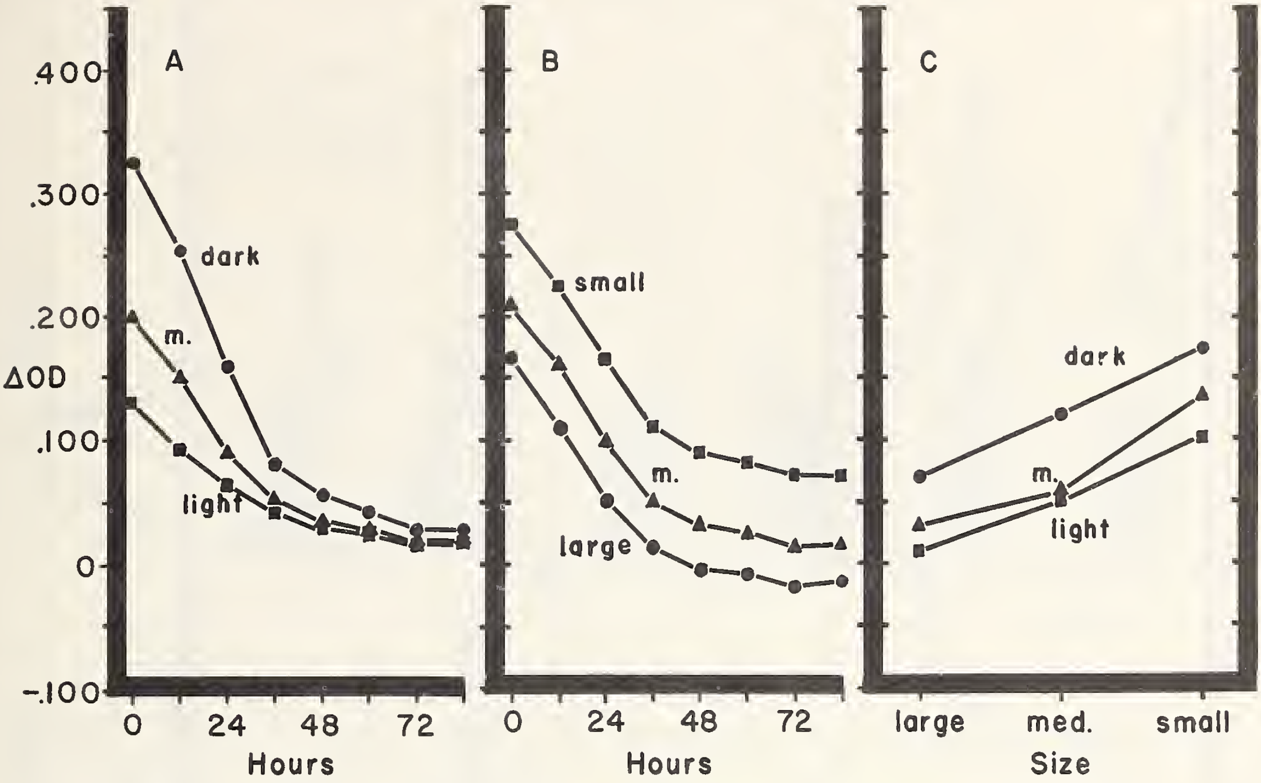

Figure 4.--Color relationships in difference meter ratings, Test 2, 1964. Color ratings in relation to (A) color groups and hours of degreening; (B) fruit size and hours of degreening; (C) color groups and fruit size.

TABLE 4.--Statistical evaluation of 1964 tests[1]

Mean square and significance

Source	DF	Test 1		Test 2	
		Plaque	Difference meter	Plaque	Difference meter
Color groups	2	**5960	**0.1412	**14122	**0.1030
Size of fruit	2	**151	**.0984	**1168	**.1576
Hours of degreening[2]	3	**18709	**.5006	**24917	**.3547
Color x size	4	**84	NS .0007	**249	**.0020
Hours x size	6	NS 12	**.0022	*50	NS .0006
Color x hours	6	**268	**.0392	**191	**.0260
Color x size x hours	12	NS 15	NS .0002	NS 26	NS .0003
Error	140	11	.0003	15	.0004

[1] Statistical symbols represent: NS = nonsignificant; * = significant at 5-percent level; ** = significant at 1-percent level.
[2] Only data for 0, 24, 48, and 72 hours were used for analyses.

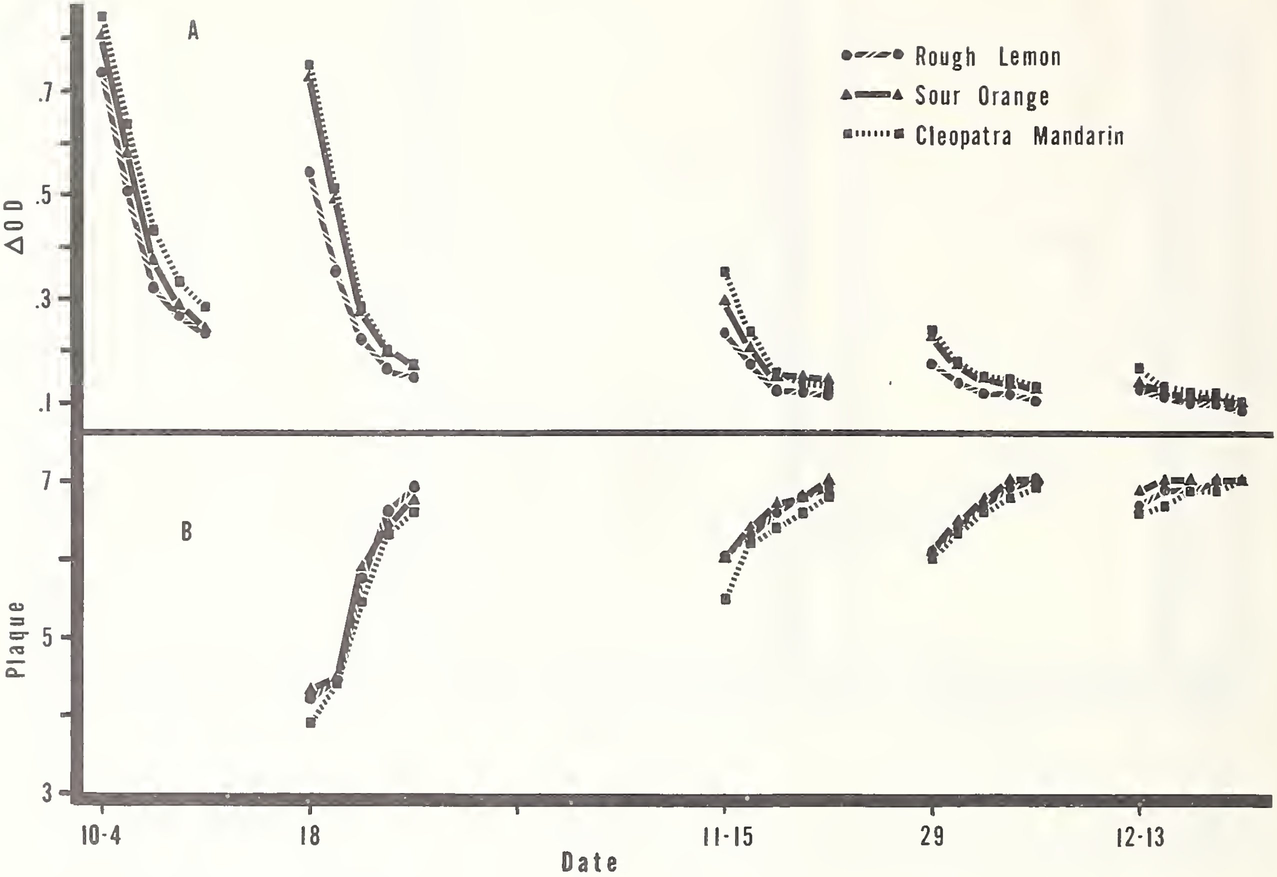

Figure 5.--Effects of rootstock on degreening response of Hamlin oranges, 1965. (A) Difference meter ratings; (B) plaque color ratings.

It is also possible that with a system such as this the fruit packed would be more uniform in color and, therefore, more salable. With the different lots of fruit coming out of degreening at different times, the packing line may be in operation continuously. Although there is some advantage to running a packinghouse at capacity for a short time, a continuous operation may be desirable in that a smaller crew could be used.

FRUIT SHRINKAGE

The greater shrinkage in oranges under degreening conditions than under storage conditions of 33° or 60° F. for the 1962 and 1963 seasons is illustrated in figure 6. Losses in height and in weight were similar. Loss in height during 40 hours of degreening was less tha 0.1 inch in all fruits, and in most it was less than 0.05 inch.

During the 1964 tests on Hamlin oranges (table 5), losses of less than one thirty-second (0.03) of an inch in diameter and one-twentieth (0.05) of an inch in height occurred during 84 hours' degreening. These were similar to or somewhat less than the comparable rate of

TABLE 5.--Effect of 84 hours' degreening on average diameter and height of 3 sizes of Hamlin oranges, 1964

Date of test and size of fruit	Diameter		Height	
	Initial	Loss	Initial	Loss
NOVEMBER 9	Inches	Inches	Inches	Inches
Small........	2.57	0.02	2.53	0.05
Medium	2.85	.02	2.84	.05
Large........	3.18	.03	3.18	.04
NOVEMBER 16				
Small........	2.64	.02	2.60	.04
Medium	2.89	.02	2.87	.04
Large........	3.10	.02	3.11	.04

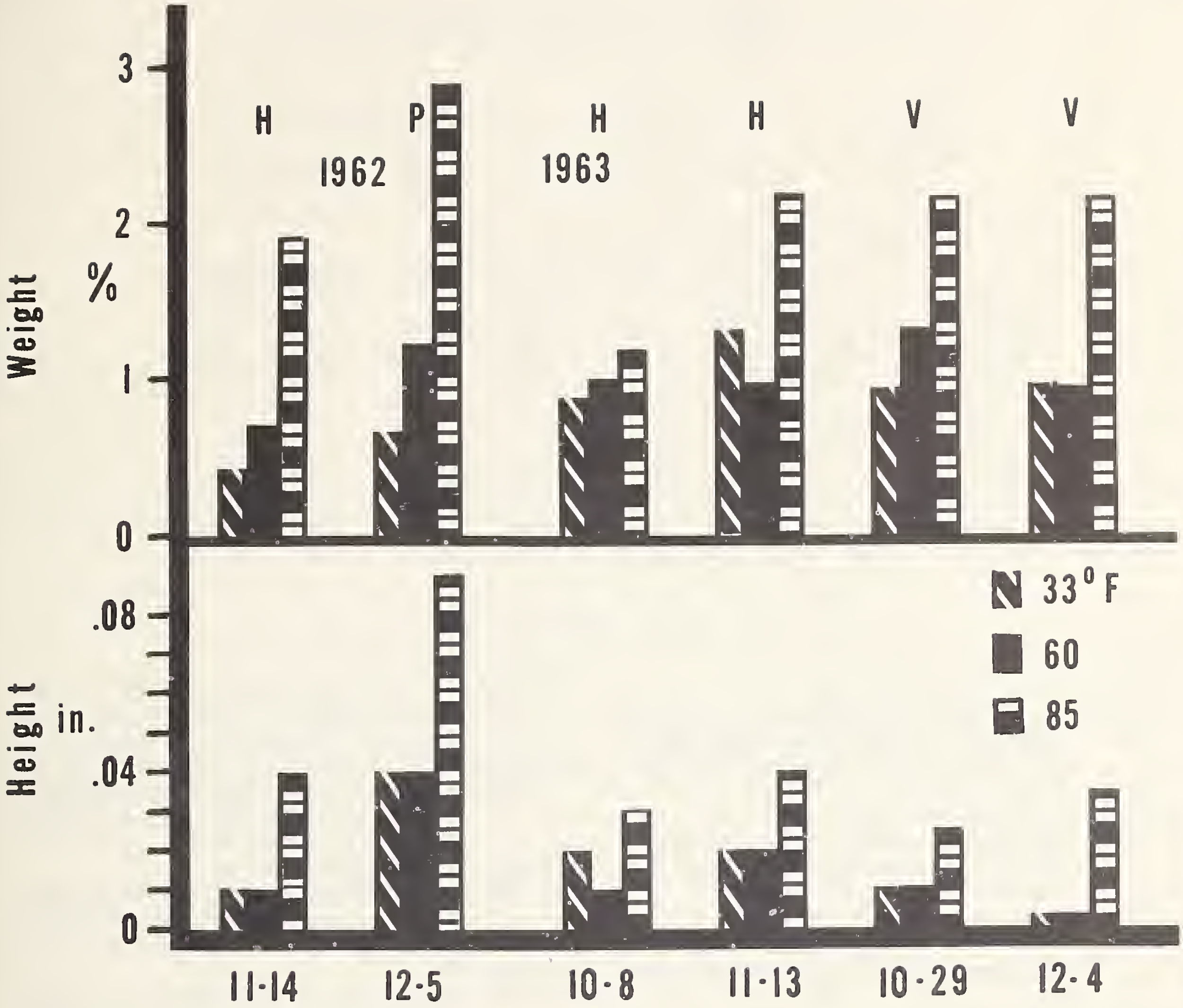

Figure 6.--Average losses in weight and height per fruit during 40 hours' storage at 33° and 60° F. and in degreening (85°). 1962 and 1963. Hamlin (H), Pineapple (P), and Valencia (V) oranges.

loss in the earlier tests. Weight losses were as great as 2.9 percent in one series. Fruit size and color had no apparent effect on percentage of weight loss (table 6).

High humidity is recommended for degreening rooms to reduce fruit shrinkage. These results show, however, that considerable losses still exist even under such conditions. Minimizing the time in degreening, therefore, would be an additional means of reducing shrinkage. These results also are useful in relation to the sizing of fruit before degreening, as is being done in a few packinghouses. With no greater changes in size than were found in these tests, this practice would appear practical. Assuming that consistent low shrinkage was maintained, this system would allow a more flexible packingline operation. However, sizing at this time in addition to color sorting would create a more difficult problem of maintaining the identity of fruit through the degreening process.

TABLE 6.--Average fruit weight and weight changes during 84 hours' degreening of Hamlin oranges, 1964

Fruit size and color	November 9			November 16		
	Initial weight	Weight loss		Initial weight	Weight loss	
FRUIT SIZE	Grams	Grams	Percent	Grams	Grams	Percent
Small	144.0	3.0	2.08	154.0	2.0	1.30
Medium	197.0	4.0	2.03	205.0	6.0	2.93
Large	265.0	5.0	1.89	251.0	6.0	2.39
FRUIT COLOR						
Dark green	201.4	3.7	1.88	203.4	5.0	2.46
Medium green	202.9	3.4	1.68	202.6	4.9	2.42
Light green	201.3	4.6	2.28	204.1	4.9	2.40

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